Lecture Module - Data Acquisition

ME3023 - Measurements in Mechanical Systems

Mechanical Engineering

Tennessee Technological University

Module 8 - Data Acquisition

Module 8 - Data Acquisition

- Topic 1 - Analog to Digital Conversion
- Topic 2 - DAQ Hardware and Applications
- Topic 3 - Sampling and Aliasing

Topic 1 - Analog to Digital Conversion

- DAQ and Computer Storage
- Number Types
- Analog to Digital Conversion and DAQ
- Activity: ADC Resolution Calculation

DAQ and Computer Storage

Types of Signals:

- **Analog** - magnitude is continuous in time
- **Discrete Time** - magnitude at points in time

  - sampling at repeated time intervals
- **Digital** - exists in discrete points in time

  - magnitude is also discrete

DAQ and Computer Storage

A data acquisition system is the portion of a measurement system that quantifies and stores data. - Theory and Design of Mechanical Measurements

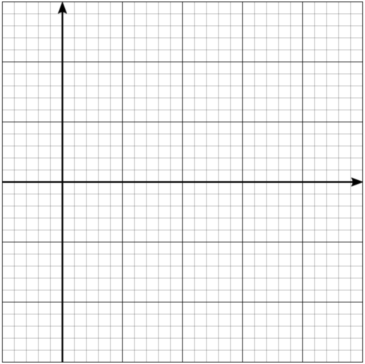


Image: T.Hill

Number Types

- Integers
  - Binary
  - Decimal
  - Hexadecimal
- Fixed Point
- Floating Point

Number Types

Binary	Decimal	Hexadecimal
0	0	0
1	1	1
10	2	2
11	3	3
100	4	4
	5	5
	6	6
	7	7
	8	8
	9	9
	10	A
	11	B

Binary	Decimal	Hexadecimal
	12	C
	13	D
	14	E
	15	F
	16	
	17	
	18	
	19	
	20	
	21	
	22	
	23	

some reference

Number Types

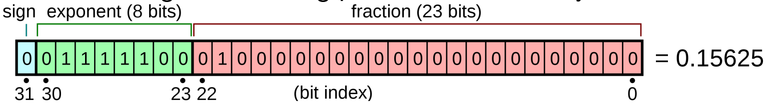
Binary	Decimal	Hex.
0	0	0
1	1	1
10	2	2
11	3	3
100	4	4

Binary	Decimal	Hex.
0	0	0
1	1	1
10	2	2
11	3	3
100	4	4

some reference

Number Types

Standard storage of a floating point value in memory



Wikipedia: IEEE Float Wikipedia: Fixed Point

Number Types

Integer

Pros:

Cons:

Examples:

Floating Point

Pros:

Cons:

Examples:

Fixed Point

Pros:

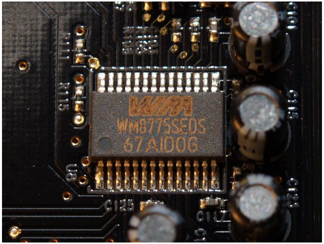
Cons:

Examples:

Text: Theory and Design for Mechanical Measurements

Analog to Digital Conversion and DAQ

In electronics, an analog-to-digital converter (ADC, A/D, or A-to-D) is a system that converts an analog signal, such as a sound picked up by a microphone or light entering a digital camera, into a digital signal. An ADC may also provide an isolated measurement such as an electronic device that converts an analog input voltage or current to a digital number representing the magnitude of the voltage or current. Typically the digital output is a two's complement binary number that is proportional to the input, but there are other possibilities.

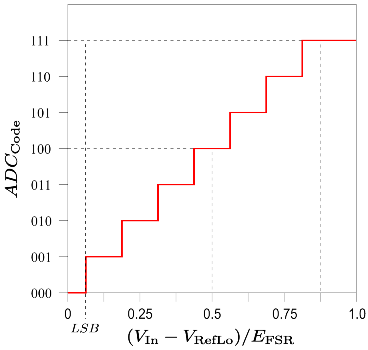


wikipedia, image

Analog to Digital Conversion and DAQ

Activity: ADC Resolution Calculation

It is important to realize the potential for data loss resulting in a reduced quality measurement based on the parameters of the analog to digital conversion process. This issue can occur when designing systems around a low-level analog to digital converter as well as when using high-end DAQ equippment.



Activity: ADC Resolution Calculation

Activity: - Consider setting up a data acquisition system to record pressure measurements in a vehicle system. Multiple sensors are available, and the DAQ device has different operating modes. Each sensor and DAQ mode has a different input and output signal ranges and different sampling frequencies.

Signal

- Measure Variable: Pressure (psi) in automobile tire
- Expected Range: 0-100 psi

Sensor+Transducer	Input Range (psi)	Output Range (volts)
A	0-200	0-3.0
B	0-120	0-0.50

DAQ Mode	Input Range (volts)	ADC Resolution
1	0 to 3.3	10bit
2	-10 to 10	12bit
3	0 to 10	12bit

Activity: ADC Resolution Calculation

Activity (continued):

1. Choose a **sensor+transducer** pair and an appropriate **DAQ mode** to record the signal shown with best (lowest) possible resolution. Support your choices with a resolution calculation for smallest detectable voltage (*volts*) and smallest detectable pressure (*psi*)

2. Approximate the sensivity of the measuement system in units of $\frac{psi}{volts}$.

NI - Smallest Detectable Change

Topic 2 - DAQ Hardware and Applications

- Signal Types and Wiring Configurations
- EMI Considerations
- Available Hardware
- Software Integration

Signal Types and Wiring Configurations

Most data acquisition devices and systems measure and record analog voltage signals and possibly additional signal types. Signal generation may also be a feature on some systems.

A voltage signal requires a **common** reference or **ground**.

Signal Sources:

- Grounded or Ground-Referenced
- Ungrounded or Floating

Measurement (DAQ) Systems:

- Common Ground
- Common Mode Voltage
- Isolated Ground

NI, Digilent
Text: Theory and Design for Mechanical Measurements

Signal Types and Wiring Configurations

Most data acquisition devices and systems measure and record analog voltage signals and possibly additional signal types. Signal generation may also be a feature on some systems.

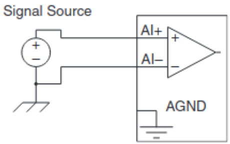
2 Major Configurations:

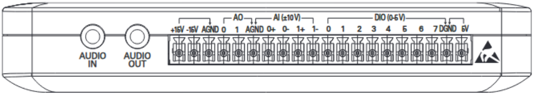
- Single-Ended Signals
  The signal is measured as a voltage between a single conductor and the **ground** which must be carried on a separate conductor or wire.
- Double-Ended (Differential) Signals
  The signal is measured as the difference between two voltages (double) carried on separate conductors, or wires. Typically a **ground** is shared between the two devices requiring a third conductor.

Read more here: MCCDAQ

Signal Types and Wiring Configurations

Ground Referenced Source Differential:

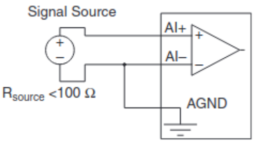


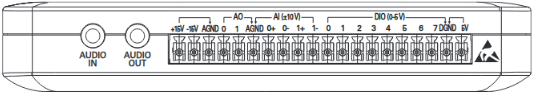


Images: NI myDAQ User Guide and Specifications

Signal Types and Wiring Configurations

Floating Source Differential:

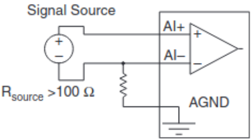


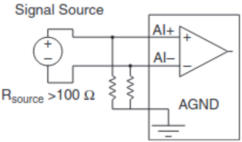


Images: NI myDAQ User Guide and Specifications

Signal Types and Wiring Configurations

Floating Source Differential with Resistors:





Images: NI myDAQ User Guide and Specifications

Signal Types and Wiring Configurations

Multiple Signal Sources:

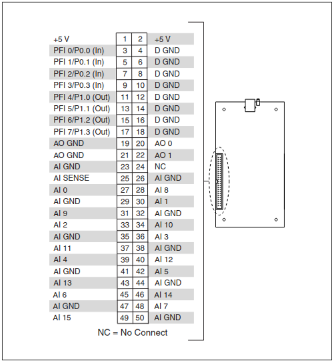


Figure 4. USB-6211 OEM Connector Pinout

Images: NI UBS 6211 User Guide and Specifications

Signal Types and Wiring Configurations

Single-Ended Signals

Pros:

Cons:

Examples:

Double-Ended Signals

Pros:

Cons:

Examples:

Text: Theory and Design for Mechanical Measurements

EMI Considerations

Electromagnetic interference (EMI), also called radio-frequency interference (RFI) when in the radio frequency spectrum, is a disturbance generated by an external source that affects an electrical circuit by electromagnetic induction, electrostatic coupling, or conduction.

A *combination* of naturally occuring and human made sources of interference is always present. The total EMI affecting a system is determined by the local conditions as well as global environmental influences.

Sources of EMI:

- Televsion transimission, celular networks, AM FM radio
- Lightening storms, solar activity
- Power transmission Lines
- Electronic devices such as computers, power supplies, motors, welders
- Intentional (weaponized) EMI

NIST

EMI Considerations

In data acquisition, electromagnetic interference (EMI) can cause reduction of signal quality and data loss due in the form of noise and or drift.

Consider the case of an analog signal transmitted from a sensor to a DAQ device. What can be done to avoid issues associated with EMI?

Methods of reducing EMI affects:

- Proximity - reduce length of signal conductors to minimum, if possible locate on same PCB or in same enclosure
- Differential signal - double ended signals are preferred when EMI is expected and close proxity is not available
- Noise rejection cables/wires - twisted pair, foil sheild, wire braided sheild, combos

wikipedia: twisted pair,Mouser-Alphawire

Available Hardware

- National Instruments
- Measurement Computing
- dSPACE
- Arduino or other

Available Hardware

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- Measurement Computing
- dSPACE
- Arduino or other

Available Hardware

Software Integration

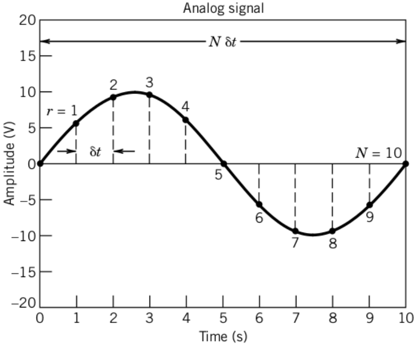
Software Integration

Topic 3 - Sampling and Aliasing

- Sampling
- The Aliasing Phenomenon
- Example by Hand
- MATLAB Example
- MATLAB Example

Sampling

... A discrete time signal usually results from the sampling of a continuous variable at repeated finite time intervals. ...



Discrete time signal

$\{y(r\delta t)\}$

r	Discrete data
0	0
1	5.9
2	9.5
3	9.5
4	5.9
5	0
6	−5.9
7	−9.5
8	−9.5
9	−5.9
10	0

Text,Figure: Theory and Design for Mechanical Measurements Ch. 7

Sampling

The Aliasing Phenomenon

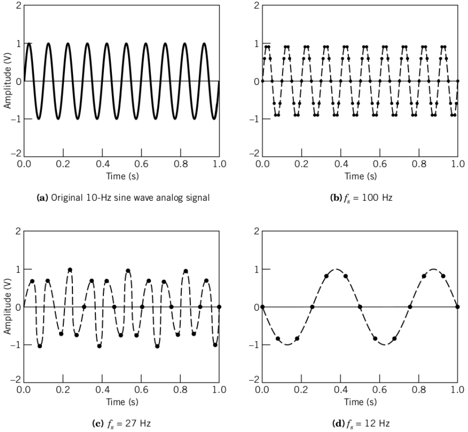


Figure: Theory and Design for Mechanical Measurements Ch. 7

Example by Hand

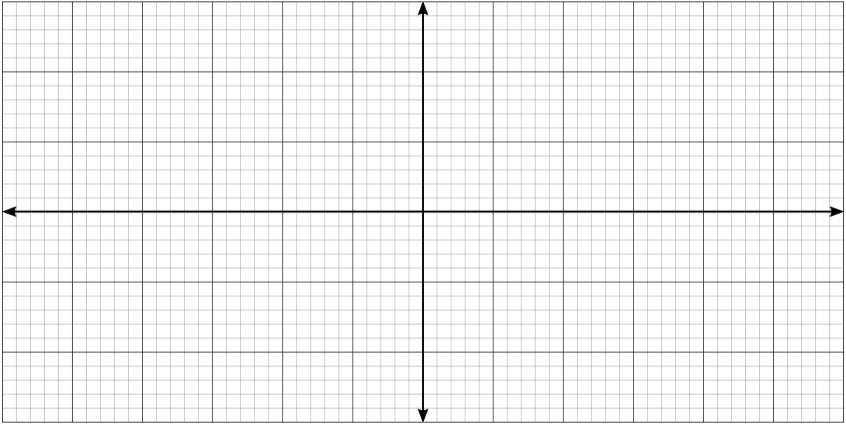


Image: T.Hill

Example by Hand

MATLAB Example

```
% ME3023 - Tennessee Technological University
% Tristan Hill - October 10, 2019 - April 14,
    2021
% Data Acquisition Topic 3 - Sampling and
    Aliasing

clear variables; close all; clc

% simulate a continuous signal
A1=5; f1=3;
w1=2*pi*f1;

dt_sim=0.001; t_stop=6;
t_sim=0:dt_sim:t_stop;
y_sim=A1*sin(w1*t_sim);
```

MATLAB Example

```
% simulate sampling the signal
dt_sam = 0.3;
t_sam=0:dt_sam:t_stop;
y_sam=A1*sin(w1*t_sam);

% show the figure
figure(1); hold on
plot(t_sim,y_sim,'-',t_sam,y_sam,'o')
axis([0 t_stop -1.2*A1 1.2*A1])
grid on
```

MATLAB code: T. Hill

Actvity

Activity: Sampling Demonstration
Use the provided MATLAB program *samplingDemo.m* to accomplish the following:

1. Adjust the input signal frequency to plot a sinusoidal signal $y(t) = Asin(\omega \cdot t) = Asin(2\pi f \cdot t)$ with an amplitude $A = 1$ (units) and approximate frequency $f = 100$ (Hz). This is the *input signal*.

2. Adjust the sampling frequency until the sampled signal correctly represents the input amplitude. Find the minimum ratio of sampling frequency to input frquency that would allow for a reasonable measurement of amplitude.

3. Adjust the sampling frequency until the sampled signal correctly represents the input frequency. Find the minimum ratio of sampling frequency to input frquency that would allow for a reasonable measurement of frequency.

Deliverables: Submit answers to all discussion questions. Include a separate screen captures or saved images as justification for the answers to part 2 and part 3.